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# Universities and knowledge-based economic growth: the case of Delft (NL)

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**Abstract:** Knowledge about new technology is a main determinant of the competitiveness of cities and regions nowadays. It reduces the amount of uncertainty of companies in their daily operations. In addition, it is a basis for the establishment of new companies and the restructuring of old ones. The availability and use of knowledge has thus a major influence on the development of urban and regional economies. An amazingly small amount of research has been done on the knowledge capacity of cities to date, i.e. urban potentials to generate, store, transfer and use knowledge. This article explores therefore, the urban knowledge capacity in a theoretical and empirical sense. Attention will be given to essential urban knowledge activities, and to the comprehensive and complex nature of the phenomena involved. In addition, various planning tools aimed at knowledge-based economic growth will be considered, with a focus on differences between the actors involved, and opportunities and constraints for success. In the empirical part, the city of Delft in the Netherlands will serve as an example, particularly regarding local policies for knowledge-based growth. Delft is an interesting case given the abundant availability of new technology and the relatively low level of local new firm formation.

## 1. Introduction

It is now widely accepted that new knowledge is one of the most important determinants of the competitiveness of cities and regions. The use of knowledge reduces the amount of uncertainty companies face in their daily operations. In addition, new technology used in product and process innovation is a basis for the establishment of new companies and the restructuring of old ones. It needs to be emphasized that the local availability of new knowledge may rest on local knowledge sources but also on local access to global knowledge networks.

An analysis of urban growth patterns in Europe in the past years has indicated net population gains particularly among medium-sized towns (Cheshire 1995). Many of them are ancient university cities, with well preserved and attractive historic cores, and a highly educated (skilled) population. Thus, it seems that cities with an abundant availability of knowledge have a relatively favourable position in competition between cities.

Knowledge manifests itself in two basic forms, namely embodied and disembodied knowledge (Geenhuizen 1994). Embodied knowledge resides in devices, equipment, machinery, and materials, as well as in human beings (ideas, expertise, skills and routines). Disembodied knowledge includes databases, manuals, patents, specifications, scientific books and journals. In addition to the basic forms of knowledge, it is important to distinguish between theoretical knowledge and applicable knowledge which is ready for use. Regarding its use, knowledge can serve as an intermediate input in production processes, but also as a final product in consumer markets. Different from material goods, knowledge can be re-used, transformed (or up-dated) and transferred in almost endless flows.

Companies satisfy their needs for knowledge by internal knowledge creation (in R and D departments or 'implicit' in production processes) and use of external sources. External knowledge is made available to firms by way of knowledge networks. The term *knowledge network* is used here to denote a set

of nodes together with the links connecting the nodes (Batten et al. 1989). Dependent on the level of analysis, nodes include individual organisations (such as the university) or human settlements such as cities and metropolitan regions. *Knowledge nodes* can be characterised by their stocks of knowledge (e.g. human capital), and capacity to generate new knowledge and connect different knowledge actors with each other (e.g. by providing opportunities for meetings such as exhibitions and conferences). The links between nodes facilitate flows of knowledge in different ways, dependent upon the type of knowledge, such as embodied and disembodied knowledge.

From an analytical point of view it is important to distinguish the following knowledge activities: the creation of new knowledge, the management of stocks of knowledge, the advancing of transfer of knowledge in view of technological innovations, education and training, and the commercial use of knowledge itself. The main actors in these fields are universities and higher educational institutes, (public) research institutes, research departments of companies, smaller technology-based companies, transfer or intermediary institutes, and governments on different levels.

The way new knowledge is created by above actors is currently changing in particular ways (Gibbons et al. 1994). There is a shift from hierarchical, disciplinary and division of labour-based knowledge production to a mode in which research problems are set across disciplinary frameworks with a strong focus on application. In addition, flexibility, response time and quality control are increasingly becoming important factors. In terms of the organisation of knowledge production, this means a greater variety of actors and sites involved: aside from universities also non-university institutes, research centres, think tanks, consultancies and government agencies. Furthermore, knowledge is increasingly being created by teams (or consortia) on a temporary basis. The composition of such teams changes frequently dependent upon the nature of the research problems and the funding of the research. As a consequence, nodes as sites may lose importance and connecting links may gain. In addition to this new nature of knowledge creation, the *delocalising* potential of new trends in university education needs to be mentioned, such as based upon distance learning, short-term intensive courses and increased self-study of students (modular structure of curriculum).

In the past years, the role of universities in local and regional economic growth has received an increased attention (cf. Charles and Howells 1992; Florax 1992). However, a small amount of research has been done on the knowledge capacity of cities by using a comprehensive approach, i.e. including potentials to generate, store, transfer, and use knowledge. This article aims therefore, first to explore the concept of urban knowledge capacity theoretically (Section 2). Furthermore, it will consider various planning tools that aim to advance the role of universities as key actors in technology-based economic growth. The focus will be on basic differences between these tools in terms of actors and objectives involved, and in terms of factors that contribute to a successful performance (Section 3). Particular attention will be given to the knowledge capacity of Delft in the Netherlands where the largest Dutch university of technology is located (Section 4), and to local policies in Delft that aim to advance a better use of the available knowledge (Section 5). The article does not offer the results of a thorough investigation of cities and their knowledge capacity. It merely tries to attract attention to this important field and to develop a number of lines for future research and policy (Section 6).

## 2. Urban knowledge capacity: theoretical reflections

Urban knowledge capacity is used here as a *comprehensive* concept – including the local creation of new knowledge, attraction of knowledge from elsewhere, use of knowledge, as well as connecting the relevant actors. Knowledge in the urban economy comes from a plethora of internal and external sources: from training and education, accumulated experience, from suppliers and customers, from professional meetings and casual chats, from local research and development, from migrant company investment and intracompany transfer, from media, libraries, data bases and patents, and from commercial generators of knowledge. The urban knowledge capacity includes five essential activities performed by urban actors (Geenhuizen et al. 1996):

- *Management of stocks of knowledge.* This includes providing access to archives, libraries, etc., and more importantly, the modernizing of skills of the resident population and labour force.
- *Creation of new knowledge.* This activity occurs well-structured and planned in universities, research institutes, and companies, and increasingly in temporary inter-organisational teams. New knowledge is also the result of unexpected events and processes, such as a casual conversation in a pub and failures in research experiments.
- *Commercial use of knowledge.* Commercial users are companies and (privatised) sections of governments. Use is concerned with clear-cut pieces of practical knowledge as well as inventions which need further development and testing.
- *Education and training.* This includes formal education such as by universities, art schools, and company schools, but also training and elaboration of local crafts using informal channels.
- *Networking* is essential in all previously mentioned activities in order to advance knowledge

transfer, for example, from creator to user. It is also essential in the creation of synergy between knowledge of different actors and disciplines. In addition, networking is necessary to improve the integration of knowledge actors in local society and to connect local actors with global sources of knowledge.

In a network approach to universities as urban nodes of knowledge creation, increasing attention is given to the analysis of *barriers* to networking (Charles and Howells 1992; Geenhuizen 1994). The potential barriers to networking between universities and the business world can be summarized as follows:

- small interest in commercialization of knowledge among university academics;
- different aims and lead times of research projects in universities and companies;
- competition and missing links between various knowledge sources and intermediaries;
- lack of transparency and appropriate image of universities as a source of knowledge.

It seems true that these types of barriers hamper particularly knowledge transfer between universities and local small and medium-sized enterprises (SME). Apart from exchange and transfer of knowledge, there is the valorization issue of knowledge producing activities. The so-called *synergetic* effect of the often multi-faceted knowledge types (science, art, fundamental and applied science) is seldom used. This 'missing link' follows among others from mental barriers, disciplinary diversity and lack of occasions to work together on joint projects.

On the other hand, there is a growing demand for knowledge networking from the side of the business world. Companies are facing an increasing uncertainty and risk due to the pervasive nature of new (generic) technologies such as information and communication technology, and new modes of production. In addition, the growing global competition and shortening of technology life cycles have progressively increased the need for new knowledge, whereas at the same time the costs and complexity of R and D have progressively grown. As a result, there is a trend among companies to satisfy their knowledge needs by using *external* sources.

In knowledge networking companies can adopt different organisational modes. Two important dimensions are the strength and duration of the ties, associated with different levels of *organisational interdependence* (Hagedoorn 1993). Extreme positions in this respect are held by casual links with small interdependence (such as short-term consultancy; out-sourcing) and links which involve a tight cooperation (such as joint ventures). From an empirical study in various European university cities it has become evident that companies have an overall preference for casual and short term links with local universities (Geenhuizen et al. 1996).

The urban knowledge capacity is a comprehensive and complex phenomenon which needs to be recognised in developing new research. The following characteristics are worth mentioning in this respect:

- multiple actor and multiple role situation;
- multi-faceted;
- changing setting of knowledge creation and education;
- multi-layer policy (management) framework.

The actors involved in the urban knowledge capacity have usually *diverse aims* in relation to knowledge, such as improving the competitive edge (firms), creation of high technology jobs (local governments), and profit maximization (real estate developers and investment banks). In addition, the principal actors may perform different roles at the same time. Universities are involved in the creation of new knowledge, education, supplying channels (meeting places), and selling new knowledge to the business world.

The urban knowledge capacity is *multi-faceted*, leading to the need for a multidisciplinary approach in research and policy. It involves, for example, aspects of science dynamics and serendipity, microeconomic behaviour of firms, sociology of clubs and informal networks, and economics of public finance. Furthermore, the *changing setting* of knowledge creation and education asks for an increased attention for dynamics of network formation and shifting places, instead of single actors at particular sites.

A further cause of complexity of the urban knowledge capacity is the *multi-layered* policy framework. The local government is important as it sets particular local conditions, such as available buildings for technology-based start-ups and housing for academic workers. At the same time, public and private actors at higher spatial scale levels have a considerable influence on the urban knowledge capacity. For example, multinationals decide to open or close down local laboratories and departments, or decide on funding of research at particular universities. National governments have a strong influence as they set the financial conditions of universities, establish policies for science and education, and influence the institutional framework to an important degree.

Given the above complexity, the next section will discuss the university as a principal node within knowledge-based cities, particularly the planning tools used to advance an improved commercial use of academic knowledge.

## 3. Urban knowledge capacity: planning tools

Collaboration between universities and industry takes many forms, such as joint research programmes, corporate funding of academic research and consulting by academic staff (Charles and Howells

1992). These types of networking are partly resting on established relationships of key academic actors with *large* enterprises. In order to stimulate the use of technology among small and medium-sized enterprises, universities and local governments make use of particular planning tools, such as transfer centres, science parks, and incubation schemes (Table 1).

*Academic transfer centres* have the primary task of intermediation for transfer including a combination of written, oral and hardware knowledge. In the Netherlands, the system of academic transfer institutes dates back to 1981. In the first years, the system has been fully subsidized by the national government, but since 1985 the national government gradually withdrew all subsidies. As a consequence, transfer centres took different development paths, some of them with a focus on the attraction and legal establishment of academic contract research, others with a broad scope of activities. At the same time, a downward trend in the activity of these centres became apparent, associated with the rise of new intermediaries in the market, i.e. transfer agencies of higher educational institutes and regionally based innovation centres (Geenhuizen 1994).

A particular type of academic transfer institutes is found in the United States, i.e. technology licensing offices (Parker and Zilbermann 1993). These institutes specialize in patenting and licensing of academic innovations. They bring inventions to market, by activities such as the evaluation of invention disclosures, application for patents, and identification of companies potentially interested in licensing. They essentially connect academic inventions, venture capitalists and companies.

The second type of organisations – *science parks* – is different from the first one in that it is much more concerned with human capital (entrepreneurship and management skills). Science parks foster new firm formation by academic staff and graduates in situ. In addition, a main objective is to advance interaction (knowledge exchange) between firms located in the park and academic workers. However, some scepticism about this objective has been expressed recently, based on experiences in Sophia Antipolis in France (cf. Longhi and Quere 1993). In a strict sense (Dalton 1992), science parks are property based initiatives which have formal and operational links with the university, aim to encourage the foundation and growth of knowledge based business, and have a management function to actively engage in the transfer of technology and business skills to the park's residents.

Science parks usually provide facilities for newly established firms in so-called incubator blocks. Many of them also provide premises and buildings for older firms in a park-like lay-out. In incubator blocks, conditions are created which advance the survival of newly established firms, such as cheap rent, flexible rent contracts and flexible units, as well as a range of supporting services, e.g. secretarial services, managerial assistance and (easy) access to venture capital.

An important potential threat to successful science park development stems from the multi-actor situation, including investment banks and real-estate agencies. When commercial interests become dominant, the danger of releasing the link with the university may arise, e.g. in terms of selection of residents (cf. Luger and Goldstein 1989).

The third tool to be discussed here, *incubation schemes*, compare with science parks in that a similar set of supportive services is provided for newly established firms. However, there is no central housing, nor premises in a park-like ambience. Start-

**Table 1.** Planning tools and their characteristics

| | Actors | Goals of university |
|---|---|---|
| Transfer Centre | University | • consultancy<br>• contract research<br>• to sell facility use |
| TLO[a] | University | • to bring inventions to market (licensing) |
| Science parks | University<br>Local government<br>Investment banks<br>Real-estate agencies<br>Development agencies | • firm formation and fostering<br>• knowledge exchange<br>• to sell facility use<br>• revenues from real-estate |
| Incubation scheme | University<br>Venture banks<br>Local government | • firm formation and fostering |
| Supportive networks | University<br>SME organisation | • firm formation and fostering |

[a] Technology Licensing Office (USA).

ups locate in faculty buildings or elsewhere. Incubation schemes face smaller risks than science parks because no real-estate development is involved. On the other hand, incubation schemes lack the appeal and image building force of science parks. A potential danger to incubation schemes is the lack of interest among students and graduates. In Western Europe, starting one's own business is not very popular among young academics, although new jobs and careers for a lifetime at large companies are becoming increasingly scarce.

In recent times, a growing number of *supportive regional networks* have been established, with universities and organisations of small technology-based firms as major players. The latter organisations have come into being in order to satisfy the members' needs for management skills, and business contacts in both social networks and formal information exchange. Some of these small business organisations also aim to recruit individuals (students and staff from the university, staff from established firms) that have a plausible business concept and an interest in starting a business. The major tasks of the university may be to provide a secretariat, financial resources, credibility, and teaching and research of technology-based entrepreneurship. Together the university and the small business organisation establish close links with other supportive actors, such as science parks and funding organisations. A recent example of such supportive networks is the one in the Linköping region in Sweden (Klofsten and Jones-Evans 1996). The success of stimulating networks can largely be ascribed to the following factors, i.e. an ability to meet real needs of young established firms, a clear focus, credibility and close relations between the stimulation organisation and the university.

It stands to reason that most of the above planning tools are no alternative measures, but are merely complementary.

## 4. Delft as a knowledge city

Delft is located in the Southern part of the so-called Randstad (Rimcity) at a distance of approximately 10 kilometres from the national political capital The Hague and the international seaport Rotterdam. It is a medium-sized town with 92,000 inhabitants (municipality) in 1994.

Although we recognise that from a scientific point of view the appropriate scale of analysis would be the city-system of the entire Rimcity or the Southern part, we prefer to focus on the *local* and *regional* level of Delft because there is a policy need to improve the employment situation here (Strategienota 1995). Growth of technology-based firms can contribute to decrease local unemployment among academics and – through multiplier effects and linkages in the local economy – among low educated people.

Delft has a cultural and technological profile which is unknown in the Netherlands. It is considered as the prototype of the Dutch canal city, which appears in its name which effectively means canal. Delft shelters ancient functions such as the first military headquarters and the first royal (stadtholder) residence, acquired in the sixteenth century. In the beginning of the seventeenth century Delft performed as a cosmopolitan centre by strongly developed skills, political autonomy, and many international contacts with scientists and artisans (Montias 1982). World-famous scientists and artists lived and worked in Delft, like Anthony van Leeuwenhoek (discoverer of microscopic life), Hugo de Groot (founder of international law), and the painter Johannes Vermeer.

The remaining section will discuss the current position of Delft University of Technology by using various indicators representing the academic functions of education and science, and employment. Some other universities will be taken into account as a framework of reference, i.e. the two remaining universities of technology in the Netherlands (University of Twente and Eindhoven University of Technology) and the State University of Leyden, the latter in view of its similar location (medium-sized town in the Rimcity).

Delft University of Technology is the largest of the three technology universities in the Netherlands with regard to the above-mentioned functions (Table 2). This is not surprising because its history goes back to 1842, when it was founded as the Royal Academy for military and civil engineers, whereas the other technical universities have only been established in the 1960s. Delft University of Technology is slightly smaller than State University Leyden in particular respects, such as number of students and diplomas granted (including PhD). Further, a comparison between the three universities of technology brings to light that the educational output of Delft in terms of doctorates is somewhat behind Twente and Eindhoven when taking the number of knowledge workers into account. But it must be admitted that Table 2 shows only the state in one particular year whereas the output normally fluctuates to a certain degree.

With 4,800 jobs (fte) Delft University of Technology is the largest employer in town (Table 2). Although the figures for the city and university used here are based upon slightly different definitions, they indicate an important local role. With a share in local employment of approximately 11% the position of Delft University of Technology is slightly more important than that of State University Leyden and much more important than that of the University of Twente and Eindhoven University of Technology (Table 2).

In addition, various other large scientific institutes

**Table 2.** Size of universities according to various indicators (1994)

| | Delft | Leyden | Twente | Eindhoven |
|---|---|---|---|---|
| *Education* | | | | |
| – Registered students | 14,062 | 16,470 | 7,042 | 5,903 |
| – Diplomas granted | 1,608 | 2,504 | 1,010 | 1,088 |
| *Science* | | | | |
| – PhD granted | 141 | 274 | 130 | 114 |
| – Knowledge workers (fte) | 2,600 | 2,000 | 1,500 | 1,700 |
| *Employment* | | | | |
| – Nr of jobs (fte) | 4,800 | 4,300 | 2,800 | 3,200 |
| – Local employment share | 11.2% | 9.1% | 4.9% | 2.9% |

*Source:* Annual Reports 1994 of Universities (1995); MECS (1995); Netherlands Central Bureau of Statistics (1995).

are located in the city of Delft, a situation which is unique in the Netherlands. Of all (six) large national technical institutes, five have headquarters or large departments in Delft. The largest is TNO (Organisation for Applied Scientific Research) with an employment of approximately 1,200 fte in Delft (Bureau Bartels 1996).

Compared with other universities of technology Delft University offers the largest variation in educational services and scientific research (Table 3). With 223 chairs it has the broadest scope in scientific fields (approximately a hundred more chairs than the University of Twente and Eindhoven University of Technology). Delft University of Technology has also the largest number of faculties which are unique in the Netherlands (eight). A further indicator of (appreciated) uniqueness is the number of foreign students. With a share of 7.1% of all students, Delft University of Technology has clearly the best position abroad (Table 3). When considering the orientation on services in the market (contract research and consultancy), Delft University of Technology performs at an average level. The share of work for third parties in its total budget is somewhat smaller than, for example, that of University of Twente (13.6 and 18.1% respectively).

Various indicators can be used to picture the nature of regional economic dynamics in view of the relationships with local universities. A useful distinction can be made between dynamics in existing firms, i.e. their orientation on innovation, and new firm formation (firm birth) and dissolution of firms (firm death). It needs however to be emphasized that these indicators measure no direct relationships between knowledge sources and firms.

With regard to innovation, input indicators (such as R and D) as well as output indicators (such as patents) can be used. According to a main input indicator, i.e. the use of product-oriented R and D in manufacturing firms, the Region of Delft is the most innovative region in the Netherlands (Table 4). Various other indicators such as the presence of an R and D department within firms and out-sourcing of R and D, confirm a high ranking of the Region of Delft within the Netherlands (SEO 1994). In view of firm dynamics, however, it appears that the Region of Delft is performing less well. With a firm birth rate of 10.5 per year the region is well below the top and equals the national average (Table 5). The same holds for the birth surplus (i.e. birth rate minus death rate).

This section can be concluded with the remarkable

**Table 3.** Characteristics of universities of technology according to various indicators (1994)

| | Delft | Twente | Eindhoven |
|---|---|---|---|
| *Scope in education and science* | | | |
| – Nr. of chairs | 223 | 120 | 125 |
| – Nr. of faculties | 13 | 10 | 7 |
| – Unique faculties[a] | 8 | 1 | 2 |
| *Market orientation* | | | |
| – Share of scientific services in budget[b] | 13.6% | 18.1% | 14.4% |
| *Orientation abroad* | | | |
| – Foreign students (share in totals) | 7.1% | 1.4% | 2.3% |

[a] Unique in the Netherlands.
[b] Work for third parties.
*Source:* Annual Reports 1994 of Universities (1995); MECS (1995).

**Table 4.** Indicator of innovation in manufacturing in the Region of Delft[a] and reference values (1992)

| | |
|---|---|
| Region of Delft | 88 |
| Largest regional value | 88 |
| Second largest value | 77 |
| National average | 65 |

[a] Corop Region.
*Source:* SEO 1994.

**Table 5.** Firm dynamics in the Region of Delft[a] and reference values (1993)

| | Birth rate[b] | Birth surplus[c] |
|---|---|---|
| Region of Delft | 10.5 | 5.5 |
| Largest regional value | 18.4 | 10.3 |
| Second largest value | 13.6 | 7.5 |
| National average | 10.9 | 5.6 |

[a] Corop Region.
[b] Newly established firms as a percentage of the stock of firms.
[c] Newly established firms minus firms dissolved as a percentage of the stock of firms.
*Source:* Unified Chambers of Commerce 1994.

observation that in the well-equipped region of Delft with many highly innovative firms, there is only a relatively low level of new firm formation. Thus, the question arises whether local knowledge institutes of Delft simply produce a small spin-off by personnel and graduates, or produce a large spin-off which does not locate in the region but somewhere else. There are strong indications for a geographically dispersed location of local spin-off, for example, based upon the fact that most academic workers live outside Delft and the region (Knight 1995). A low preference for starting one's own business among graduates may, however, not be excluded. Students are often attracted to Delft with a job in mind in large and medium-sized multinationals located in the region of Rotterdam and The Hague.

## 5. Knowledge policy in Delft

A knowledge policy has never been established for Delft in relation to local and regional economic growth. Various initiatives have been taken in the recent past, but these were often isolated and not embedded in a comprehensive regional policy. In addition, the initiatives were not very appealing and transparent. Only since last year, the local government has realized that the economic potential of Delft as a knowledge city deserves to be better used, including an improved marketing (Strategienota 1995). The main points of concern in a new local knowledge policy can be summarized as follows:

- *Physical planning*: housing for top managers as well as students; premises and buildings for newly established and young innovative firms; reducing mono-functionality in city design.
- *Supportive economic policy* in collaboration with other actors: supply of venture capital and management support, organisation of knowledge transfer and knowledge exchange.
- Advancing the position of Delft as an *international knowledge node* (conferences, exhibitions, summer courses etc.), including knowledge tourism.
- *Upgrading the cultural level* of Delft by improving cultural services, arts and architecture.
- *Creating a broad carrying capacity* for Delft as a knowledge city among local citizens, educational institutes and companies (SMEs).
- A further development of Delft as a knowledge city by *improved city-marketing*.

It is interesting to see that what has been missing in Delft for a long time – an *integration* of the university in the local community – (Knight 1995), is now one of the suggested policy aims. Improving local support for a knowledge-based economy and reducing the 'brain drain' by planning high-quality residential areas for young academics and academic top managers will be important ways to reach this particular aim of local integration.

It needs to be emphasized that the position of Delft in regional economic policy is totally different from that of Enschede in Twente. The University of Twente has been established predominantly for improving the regional economy. Not surprisingly, it performs a major task in advancing processes of academic spin-off. In its strategic mission to develop the region's economy, a successful supportive scheme for innovative entrepreneurs (i.e. the Temporary Entrepreneur Posts (TOP) scheme) and a science park have set the scene since the early 1980s.

Since its establishment in 1984 the TOP scheme – as an incubation scheme – has enabled the university to provide 180 young (innovative) entrepreneurs with managerial advice and financial support (loans). Currently, the goal is to make available twelve TOP posts annually (Annual Report 1994). In addition, a science park has been established in 1981 which now includes more than hundred firms with 10 jobs on average. Within the framework of the Netherlands this park is rather successful in new firm formation (Geenhuizen and Nijkamp 1996) (Appendix 1).

The city of Delft offers a number of buildings with the aim to attract young innovative firms, but there is no science park in the strict sense. The current initiative of the university, local government, Chamber of Commerce and various private actors merely includes an incubation scheme (Working Committee 1996). This initiative aims to advance

local firm formation among young graduates in the following ways:

- *The promotion of entrepreneurship* throughout the university, particularly to focus the curriculum on entrepreneurship.
- Similar to the TOP in Twente, the creation of *temporary posts for new entrepreneurs* as an incubation stage (DOP scheme). During one year these entrepreneurs continue to develop their product, establish a business plan and improve their entrepreneurial skills. In this year they receive a 'salary' as a loan.
- Establishment of a *venture capital fund* with young graduates as the target group, and the supply of a package of supportive services, such as housing and technical facilities (by the university).

What is new in this initiative is its *comprehensive* character, its broad support and its concern to make entrepreneurship more popular among students and other actors at Delft University of Technology.

## 6. Research and policy implications

The university as an urban knowledge node has rarely been investigated empirically in relation to the use of knowledge and innovation in the local (regional) economy. There is a need to map the knowledge flows (and vehicles) by means of an actor-oriented network analysis, with a particular emphasis on the relevance of knowledge for corporate innovation and new firm formation. The case of Delft has illustrated the need for a thorough investigation of the location pattern of spin-off of its university. It is unknown to what extent the low firm birth rate in the region (in view of its large knowledge supply) is caused by a spatially dispersed firm formation (e.g. in adjacent regions) or by barriers to firm formation among academic personnel and graduates. When the former process is at hand, it is important to know what mechanisms direct spin-off to regions outside Delft. When the latter situation is true, barriers to new firm formation need to be identified and removed.

Regarding policy implications, two components deserve to be stressed, namely (1) the university as a knowledge node with potentials for spin-off and (2) the interaction between universities and local (regional) actors. With regard to the first component, the mentality at universities needs to be changed in favour of starting a private business. We suggest in general the following ways (Bureau Bartels 1996; Geenhuizen and Nijkamp 1996):

- To make 'starting a company' popular among students, and to devote a part of the *curriculum* to entrepreneurial skills, not only in the second part of the study but right from the beginning.
- To give successful academic entrepreneurs strong attention in academic media in order to create '*role models*' and '*success stories*'.
- To create *incubation schemes* with a comprehensive package, like the one in Twente and the forthcoming one in Delft.
- To establish (part-time) *chairs on knowledge-based entrepreneurship* at universities. The chair holders act as managers of applied knowledge in their faculties. They provide education in entrepreneurial skills and innovation management, and act as supervisors of incubation schemes in their faculties.

As regards the second component, there is clearly a need for improvement of interaction with technology-based small and medium-sized enterprises. In this respect it is important to increase the transparency of academic services and improve their accessibility. We suggest the following policy ingredients in view of beneficial university-small business relationships (Bartels 1996; Geenhuizen and Nijkamp 1996):

- To establish a *service centre* for small and medium-sized enterprises where small and less advanced research problems can be solved, and applied knowledge of the university can be made accessible. This service centre is preferably to be managed on a joint basis (university and companies).
- To make knowledge transfer to small and medium-sized enterprises *more popular* among academics by providing incentives such as a price (bonus).
- To make innovations and new ideas *better known* among small and medium-sized enterprises, for example, by means of an annual directory and regular meetings.
- To establish *regional knowledge circles* with manufacturers, suppliers and clients, as well as the university in order to communicate on (market-driven) research issues.

The above ingredients illustrate particular comprehensive ways in which the role of urban universities can be improved in order to benefit more from their knowledge potentials. However, the complexity of the urban knowledge capacity asks for a thorough co-ordination of initiatives in order to avoid duplication of work and lack of transparency. At the same time, the establishment of policies in these areas need to be based on *participatory* decision making, in order to guarantee a sufficient support among the different actors involved.

With regard to research, we can conclude that cross-comparative analysis of various university towns would be needed in order to investigate the self-organizing and propelling opportunities of scientific research and educational institutes. The focus of such an analysis would particularly be on the identification of both site-specific and generic critical success conditions for knowledge-based economic growth.

## Appendix 1. Science Parks in the Netherlands (1993)

| Town and university[a] | Region[b] | Starting year | Size (ha) | Firms | Jobs |
|---|---|---|---|---|---|
| Enschede (T) | P | 1981 | 18.5 | 106 | 1115 |
| Leiden (G) | C | 1984 | 30 | 25 | 640 |
| Groningen (G) | P | 1988 | 60 | 51 | 460 |
| Nijmegen (G) | I | 1989 | 1.5 | 25 | 100 |
| Wageningen (A) | I | 1989 | 5.5 | 39 | 400 |
| Amsterdam (G) | C | 1991 | 20 | 20 | 150 |

[a] T = University of Technology, G = General University, A = University of Agriculture.
[b] Regional location in the Netherlands: P = Periphery, I = Intermediate location, C = Core (Randstad).
*Source:* Adapted from Bartels and Wolff (1993), p. 1039.

### Note

1. Hans Rijckenberg has mainly contributed to this paper in Section 4. The first two authors are responsible for all sections.

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